Fine tuning percussion - a new educational approach

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Abstract

The tuning of acoustic drums rarely has a formal education method yet the quality of drum sound can have a significant effect on the success of a recording project. Drum tuning is a largely subjective matter and is often considered something of a 'dark art' amongst emerging drummers.

One popular method involved in drum tuning is to 'clear' or 'equalise' the drumhead, to ensure an even response by tapping the drumhead around the perimeter of the drum and checking that a consistent sound is achieved at all locations. This technique is discussed in a number of popular texts and magazine articles, but to date has not been evaluated in a scientific context. Thus, no formal or quantifiable method of educating a technician in clearing the drumhead has previously existed. It is shown that it is possible to quantify how uniform the drumhead tuning is via simple acoustic analysis; i.e. with a drumstick and microphone. Furthermore, a drumhead with a non-uniform response exhibits beat-frequencies, producing an uneven profile to the drum response decay envelope.

It is apparent that while many expert musicians have the ability to tune drums by ear, an intelligent tuning aid provides benefits to those who are still learning their trade. The visual feedback produced by the novel and bespoke analysis software used in this paper can help musicians and producers make more informed choices with regards to their drum sound. Furthermore, the developed methods for drum tuning allow the development of a standardised education method for assisting and accelerating the learning of this skill.

1 Introduction

Many expert musicians consider the tuning of the drum kit to be critical in making the drums 'sound good'. Accounts by drummers and music producers highlight the value of tuning knowledge, such as those by Ranscombe (2006b), Seymour (2010) and Gatzen (2006). One particular strategy for drum tuning is often to produce a uniform acoustic response of the drumhead when excited around its perimeter. This is often referred to as 'clearing' or 'equalising' the drumhead. Other tuning strategies, subject to continuing research by the authors, include adjusting frequency response ratios between the batter and resonant drumheads, tuning the relative behavior of the individual drums in a drum kit and manipulating attack and decay envelopes (Toulson et. al, 2008). This article, however, focuses solely on the particular tuning strategy of clearing the drumhead.

Detailed scientific analysis on cylindrical drums has been performed by Rossing (2000) and Worland (2010), however much of the scientific research performed on acoustic drums has focused on the physical behavior of the drum, as opposed to its acoustic response.

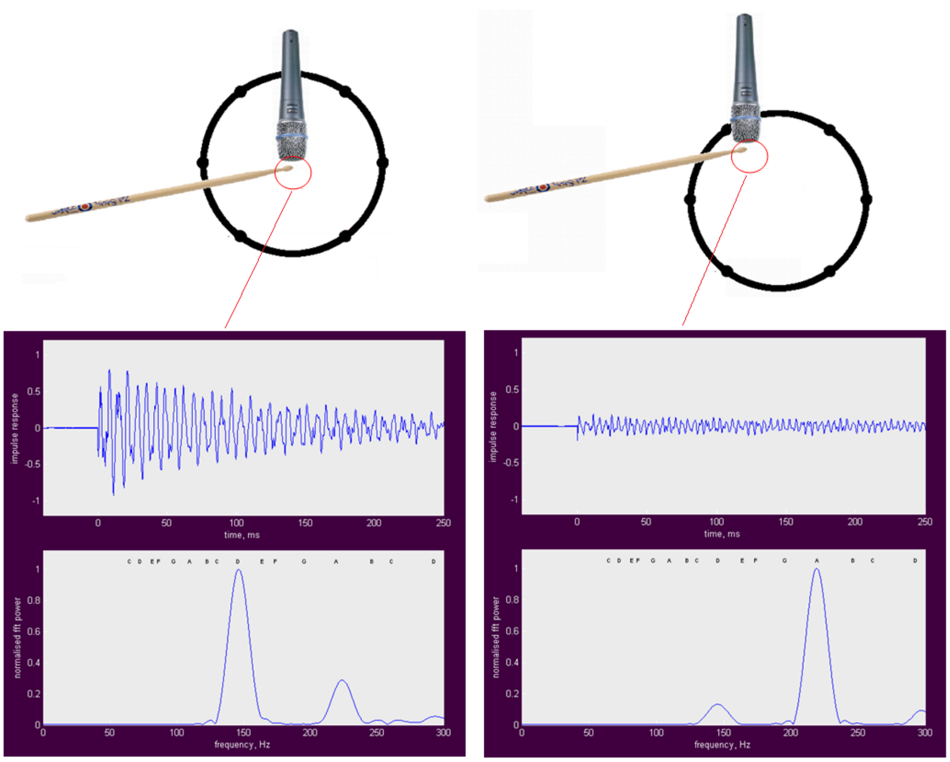
The research outlined here focuses on the acoustic response of cylindrical drums with both a batter and resonant head in place, i.e. the “drum” components of a modern drum kit. This research provides analysis of the drumhead response at locations around the perimeter of the drum with particular respect to the value of this knowledge in a music performance and production context. The research shows that a uniform response around the perimeter is indeed possible and quantifiable and, therefore, simple analysis methods can be utilised to assist musicians in clearing the drumhead.

This paper discusses prior literature regarding drums from both scientific and popular viewpoints, along with literature on learning methods. Experimentation and analysis is discussed with the results evaluated. A novel display system is considered for assisting and quantifying the difference between a cleared and ‘non-cleared drumhead’, and hence providing an education tool and method to assist percussionists and music producers in achieving a desired drum sound.

2 Background

2.1 'Clearing' the Drumhead

The physics of acoustic drums can be partially described using circular membrane theory based on Bessel functions. Bessel functions are solutions to Bessel’s equation and have been discussed by Rossing and Fletcher (2004) in “Principles of Vibration and Sound”.



Centre impulse and response. **Edge impulse and response.**

Figure 1. Centre and edge impulse responses produced when a drum is struck at different locations.

The fundamental frequency and second partial are the predominant frequencies when a drumstick strikes a drumhead naturally. These two frequencies, the (01) mode, f_0, and the (11) mode, f_1, are the most powerful modes produced by simple excitation, with the fundamental mode being the predominant frequency produced when the drum is struck at or near the centre of the head, as shown in Figure 1. The (11) mode, $f_{1,}$ becomes most prominent when the drumhead is excited around the perimeter, and it is this frequency that is often of most concern to expert musicians when they tune the acoustic drum by ear.

Worland (2010) investigated the (11) mode in drum tuning a single head under non-uniform tension and discusses “frequency splitting”, where the (11) mode in a drum with a single head splits into two distinct frequency peaks. He states that in ideal circumstances, “the (11) mode produces a single frequency and occurs with its nodal diameter oriented in any direction”. The nodal diameter of the (11) mode can be seen in Figure 1 as a grey line across the drumhead. Frequency splitting has also been noted in experiments performed on a kettledrum by Rhaouti et al. (1999), along with the presence of beat frequencies when these split frequency peaks occur.

Professional musicians often have the ability to tune the drum kit by ear, effectively listening for a desired drumhead response. Gatzen (2006) discusses the importance of clearing the drumhead when tuning and explains that:

> “Equalised tuning is by far the single most important technique I use”

2.2 Drum Tuning in Education

In comparison to other instruments, drums are described as being “much more difficult and challenging” to tune (Schroedl, 2002). It is widely regarded that it can take months or even years of practice before a drummer can effectively tune their drum by ear alone (Tama-Drums, 2010). From a novice’s perspective, drum tuning is a considerable challenge with no quantified educational methods available to assist with learning the skill (Toulson et. Al, 2008). Research performed with focus groups indicates that novices would embrace the ability to tune the kit to a particular genre or to replicate the sound of their favorite musician.

Drum tuning guides, for example Ranscombe (2006b) and Seymour (2010), often discuss the importance of achieving a uniform pitch around the perimeter. If the frequency response is not uniform these frequencies interfere, causing a beat frequency that can be seen in the waveform (Richardson and Toulson, 2010). Clearing the drumhead, or removing these unwanted frequencies by tuning each point around the perimeter, creates a uniform response that Ranscombe (2006a) describes as a “nice tone that decays with a smooth even note”.

Although there are a number of mechanical devices that measure drumhead tension to provide a rough guide towards the tuning of an acoustic drum, these devices lack the sensitivity and sophistication needed to aid fine-tuning. These devices do not provide intelligible closed-loop feedback to the musician, they merely state whether the tension of the drumhead is consistent.

It has been recognised that there is a need to bridge the skills and knowledge gap between experts and novices in music and music production (Toulson, 2009). The challenge in education with regards to drum tuning is the lack of a standardised tuning method, there is no one way to make a drum kit sound good. Likewise, whilst some learners may readily accept the need for scientific and engineering learning in their approach to drum tuning, others may not, instead relying solely on information from popular guides such as those found in magazines or a trial and error approach to drum tuning.

Students have a variety of learning approaches, with one method, VARK, suggesting four different learner types (V)isual, (A)ural, (R)ead/write, and (K)kinaesthetic (Fleming and Baume 2006). Students often use a combination of methods in their learning (Leite et al. 2010), and it can be seen how the VARK perceptual preferences can be applied to drum tuning. Kinaesthetic learners, those who learning by doing, can learn to tune an instrument through repeated practice and trial and error. Those who learn best through written materials, the read/write learners, may get most benefit through theoretical knowledge on tuning through reading articles/books/guides on drum tuning. The learners who learn best through listening, the auditory learners, have access to audio CDs in drum tuning books, and can tune by listening to how alterations in tuning affect drum sound.

In drum tuning the predominantly visual learner is the one at a significant disadvantage. Learning to tune an instrument visually is possible. Many musicians, for example guitarists, rely on visual feedback from an electronic tuner in order to tune their instruments, however no such commercial device exists to aid drum tuning.

3 Experimental Data

3.1 Methodology for Analysis

A 30-cm tom drum from a Gretsch Catalina Club Jazz kit was used in the following experiments. The drum had an Evans EC2 batter head and Aquarian Classic Clear resonant head. The drum was rested on a standard drum stand with a Shure BETA 57A microphone held securely 10 cm above the drum angled toward the location of the drum stroke. The drum was struck and data captured approximately 5 cm from the edge at 10 locations - one at each lug and at points equidistant between lugs. These locations are at each lug (1, 2, 3, 4 and 5) and halfway between one lug and the next (1+, 2+, 3+, 4+ and 5+), as shown in Figure 2. A consistent stroke height of approximately 5 cm was used. As the experimental modal analysis used is concerned with the free vibration of the drumhead, precise excitation was not necessarily a significant factor in achieving reliable results.

The acoustic response for each excitation was captured at 44.1 kHz to 16-bit resolution. Using the Matlab Fast Fourier Transform (Mathworks, 2010), a frequency spectrum is generated from a 5000 sample data window and processed using a Hanning window function. The Matlab FFT function allows use of zero padding (Weeks, 2010) to interpolate the raw FFT data, resulting in a smooth spectrum with very close data points. In this instance, the FFT was resolved to data points spaced at 0.0842 Hz intervals.

Where experiments were performed with both resonant and batter head in place the resonant head was tuned to a desired, uniform response before fine tuning the batter head.

3.2 Tuning to a Uniform Response

As discussed, a uniform frequency response around the perimeter of the drumhead is a desirable aspect of tuning. Frequency analysis can be used to provide quantified, visual feedback on the tuning of drums. It is possible to ‘clear’ a drumhead by making slight adjustments of less than a quarter of a turn to each tension rod (lug) in response to analysis of the frequency spectra for each data reading.

A uniform frequency response around the perimeter of the drumhead is achieved via analysis of the f_1 mode. This uniform frequency for f_1 can be seen from the results in Table 1 and Table 2 which show the peak frequencies when the response was analysed at 10 locations around the drumhead. The results in Table 1 and Table 2 show that it is possible to tune a drumhead so that each location near the edge of the drumhead has an equal and single identifiable f_1 frequency peak, as shown in Figure 3, which relates to the data in Table 1. Table 1 and Table 2 show the uniform frequency achieved at 220 Hz ±0.5 (0.22%) and 175 Hz ±0.8 (0.45%) with both drumheads. These frequencies were specifically chosen to correspond to notes on the musical scale, F3 (174.6 Hz) and A3 (220 Hz).

Figure 4 shows the waveform of a drumhead with a uniform frequency response, it can be seen that a smooth, ‘beat free’ decay is present. Here, beating was not audible when the drum was struck. Much like the tuning of a timpani, the removal of ‘beating’ from the waveform is advantageous and necessary in the tuning of a cylindrical drum.

The experimental analysis used shows that when the drumhead has been ‘cleared’, f_1 is consistent around the drumhead, as shown in Figure 5, which shows results for the 220 Hz tuning used in Table 1; the results have been filtered with a 5th order Butterworth filter applied to $0{:}5f_1$ to $1{:}5f_1$ so as to isolate f_1 for analysis. Here it can be seen that f_1 is virtually identical at each point to an accuracy of ±0.5 Hz, and that a smooth decay, Figure 4, is present. This is a novel method for quantifying that a drumhead is in tune by exhibiting a uniform response. This method provides simple visual and numerical feedback which could be used to aid drum tuning.

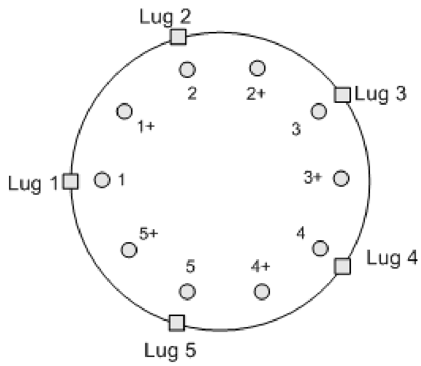


Figure 2: The analysis sequence and stroke locations used on a 5-lug tom drum

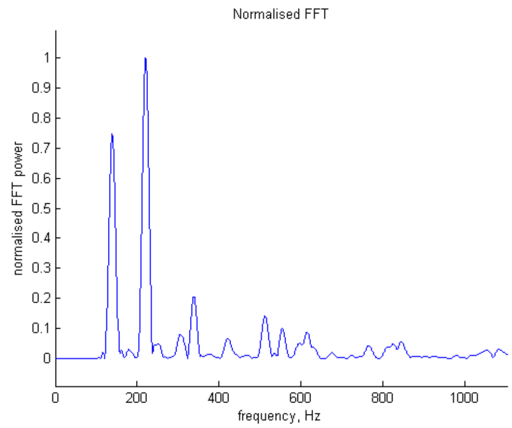


Figure 3: Normalised FFT of the drum acoustic with uniform frequency response struck at the edge.

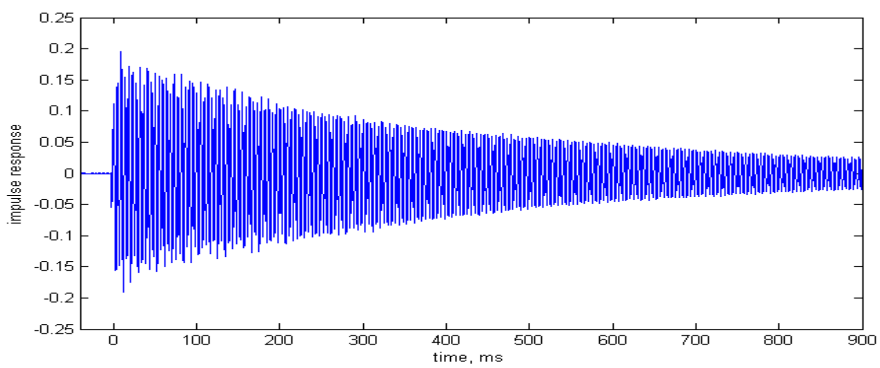


Figure 4: Example waveform produced when uniform frequency for f_1 is achieved for a 30-cm tom drum with a both drumheads.

Tension Rod	1	1+	2	2+	3	3+	4	4+	5	5+
Frequency (Hz)	220.5	220.1	219.7	220.0	220.3	220.5	220.4	219.9	220.0	220.3

Table 1: The average f_1 frequency present around a drumhead on a 30-cm tom drum tuned to 220 Hz with both heads.

Tension Rod	1	1+	2	2+	3	3+	4	4+	5	5+
Frequency (Hz)	175.7	175.5	175.4	175.1	175.0	175.5	175.8	175.1	174.8	175.3

Table 2: The average f_1 frequency present around a drumhead on a 30-cm tom drum tuned to 175 Hz with both heads.

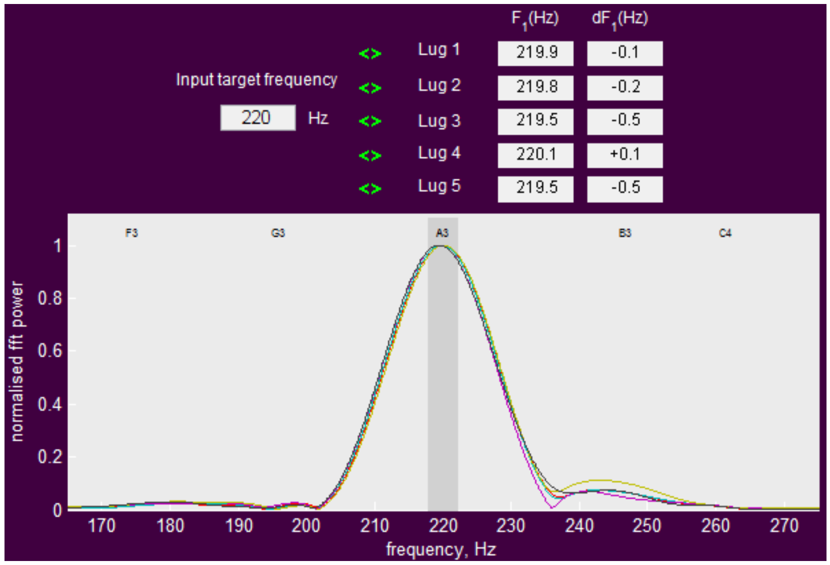


Figure 5: Uniform frequency (220 Hz) for f_1 for a 30-cm tom drum with both drumheads (5^{th} order Butterworth filter applied to band $0:5f_1$ to $1:5f_1$).

3.3 Non-uniform Tunings

Experiments have shown that there are clear fluctuations in the envelope of a ‘detuned’ or 'non-cleared' drum. That is, the drum has been altered so that it no longer has a uniform f_1 exhibited around the perimeter of the head and a smooth decay profile.

When one tension rod is slowly altered at 1/8th of a turn at a time, from 0 turns to 0.75 turns, the peak frequency observed at each lug changes, as shown in Table 3. Here a 20000 sample data window and 35-cm 8-lug drum was used. The drum was initially tuned to a uniform frequency response and it is clearly visible that frequency splitting occurs as the drum is detuned at rods 1 and 5. Figure 6 shows the effect of having a tension rod loosened in $1/8^{th}$-turn increments whilst Figure 7 shows that opposite locations on the drum tend to have similar frequency response profiles as the drum is detuned.

Detuning opposite tension rods by just 0.75 turns has a significant result on the overall spectrum. As one tension rod is altered the frequencies begin to diverge. This frequency splitting increases as changes in the tension of the head at a single point and the split between frequencies reaches a maximum of 16.1 Hz between lug 4 and lug 7 at 0.75 turns out of tune.

Figure 8 shows the waveform produced when a lug is altered by one turn and here it can be clearly seen that the smooth decay of the drum sound is no longer present. Figure 9 shows the f_1 frequency produced by a tom drum struck at each lug. In Figure 9a a uniform f_1 frequency of 220 Hz (A3) can be seen at all locations. Figure 9b shows the same tom tuned to produce a non-uniform f_1 frequency and it can be seen that f_1 at tuning lugs 2 and 5 are within a tolerance of 1% of the desired frequency (220 Hz), whereas lugs 1 and 4 are tuned high and 3 and 6 are tuned low. This non-uniform tuning creates an uneven decay profile for the drum, similar to that as shown, for example, in Figure 10.

A drumhead with a uniform frequency response will produce a smooth decay curve, whereas as the drum becomes less well tuned, the drumhead begins to ‘beat’. The current research shows that a well-tuned drum will minimise beat frequencies. When the drum is tuned, only a single predominant frequency peak is present around the perimeter of the drum. However, as the drum is detuned this main peak frequency splits into 2 peaks. This furthermore correlates with Gatzen’s (2006) observation that:

“You are more able to hear a single pitch the more even your tuning is becoming”

It is possible to define a ‘cleared’ drumhead as one which has a uniform peak frequency response when excited around the perimeter. The waveform of the drum will exhibit a steady decay with no beat frequencies present.

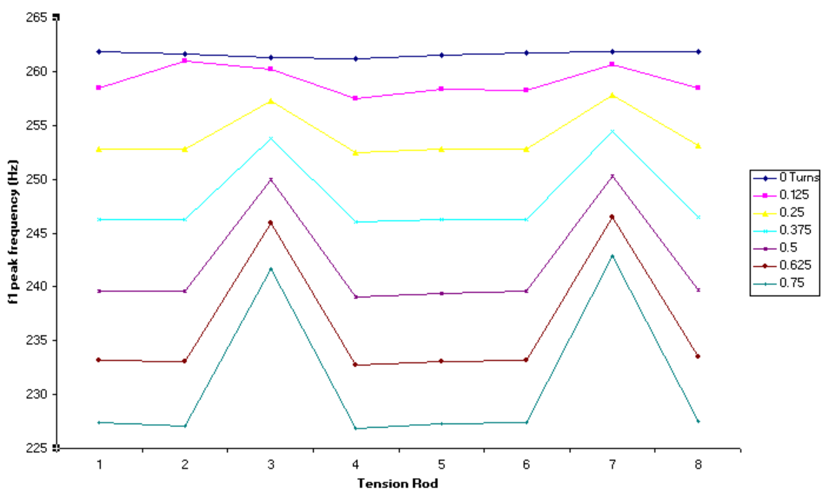


Figure 6: Shows how detuning a single lug affects the peak frequencies around a drumhead.

	Tuning lug							
Tuning	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
0 Turns	261.8	261.6	261.3	261.2	261.5	261.7	261.8	261.8
0.125 Turns	258.5	261.0	260.2	257.5	258.3	258.2	260.6	258.5
0.25 Turns	252.8	252.8	257.3	252.5	252.8	252.8	257.8	253.1
0.375 Turns	246.2	246.2	253.8	246.0	246.2	246.3	254.4	246.5
0.5 Turn	239.6	239.6	250.0	239.1	239.4	239.6	250.3	239.7
0.625 Turns	233.2	233.1	245.9	232.7	233.1	233.2	246.5	233.5
0.75 Turns	227.4	227.1	241.7	226.8	227.3	227.4	242.9	227.5

Table 3: Peak f_1 frequencies (Hz) around the batter head of a 35-cm tom as tension rods 1 and 5 are detuned.

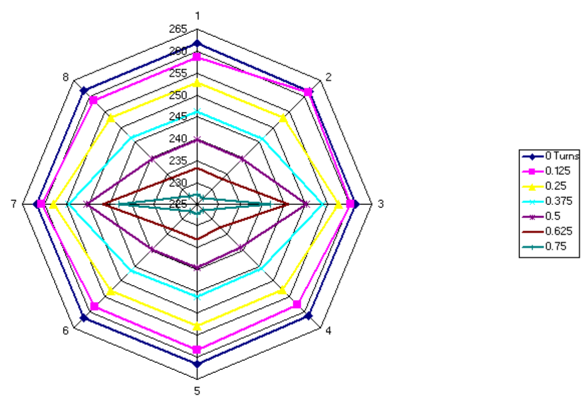


Figure 7: f_1 data from table 3 plotted in a polar frequency chart for each tuning lug

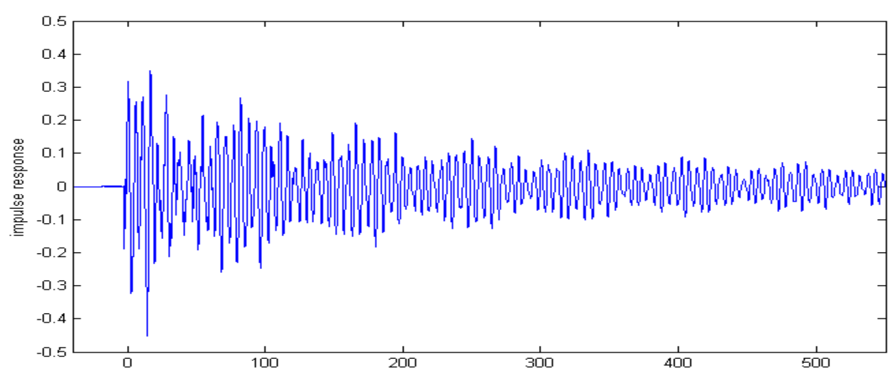


Figure 8: Waveform showing visible beating with one lug altered by one whole turn.

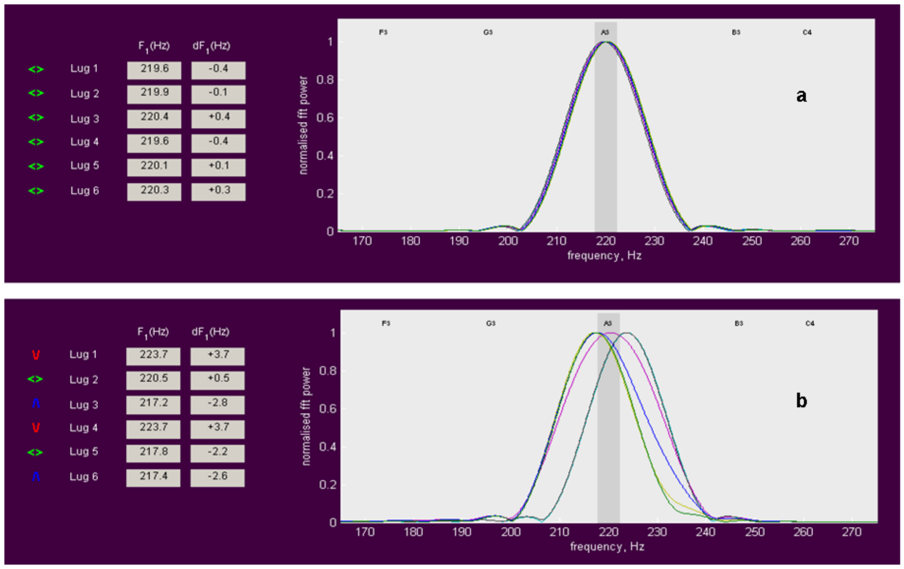


Figure 9: Analysis of the f_1 frequency for (a) a uniform response and (b) a non-uniform response (5^{th} order Butterworth filter applied to band $0:5f_1$ to $1:5f_1$).

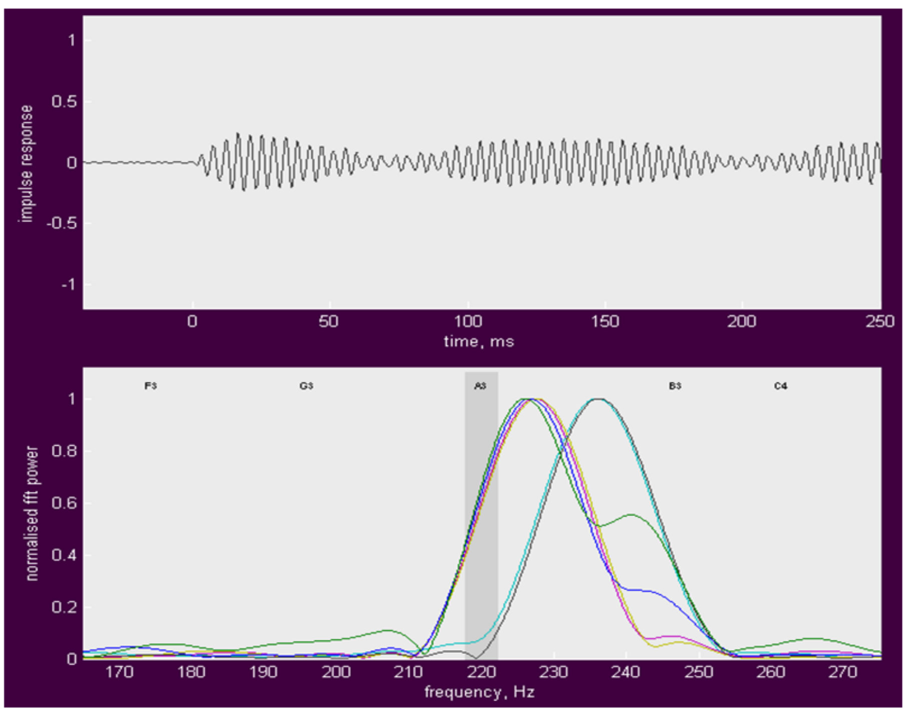


Figure 10: Waveform showing visible beating as the f_1 frequencies diverge (5^{th} order Butterworth filter applied to band $0:5f_1$ to $1:5f_1$).

4 Conclusions

The research outlined in this paper shows that a uniform frequency response for the f_1 frequency and smooth decay profile are achievable and desirable aspects of tuning for cylindrical drums. It has also been shown that it is possible to tune the f_1 frequency in the drum to a specifically chosen frequency or a musical note.

Specific responses at multiple strike locations are used to determine whether the drum produces a uniform frequency response around the perimeter. The results show that a drum can be accurately fine-tuned to provide a uniform response around the perimeter, whilst, with only small changes of drum tuning, a frequency split occurs causing the drum to fall out of tune and beat frequencies to appear.

The current research shows that it is possible to tune the drum to a uniform acoustic response via microphone analysis techniques, scientifically tuning to a uniform frequency response produces a drum sound consistent with the qualitative descriptors used by percussionists. Understanding of these factors in combination with the analysis techniques outlined in this paper can be used in a drum tuning framework.

The analysis software used in this paper is capable of providing visual feedback to aid the tuning process. Where frequency splitting occurs, plots of the (11) mode for each hit location are superimposed, providing a visual indication of which tuning rod needs to be altered in order to bring the drumhead into tune with itself.

Given that minimisation of beating in the envelope and frequency splitting in the spectrum are desired attributes, the current research shows that it is possible to achieve these aims by using feedback from the spectra and envelope profiles. This alters the particular aspect of drum tuning from an audible process of tuning 'by ear', a skill which may take many years to develop, to a visual process where quantified feedback is provided to aid and speed the process of drum tuning.

This research shows a uniform frequency response for f_1 modes are achievable to a high degree of precision (less than 1% difference in values of f_1 when excited and measured around the perimeter of the drumhead). The research concludes a scientific approach to drum tuning, using novel analysis methods, can be used to educate novices on the tuning of drums and to provide visual feedback to assist in the drum tuning.

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